PUMPING STATION COST AND EFFICIENCY RECORDS[1]

By Mark Wolff

In a paper entitled "Interpretation of Water Works Accounts" read before the last annual convention, the author, in referring to modern accounting systems for water works, stated: "It was planned to illustrate or describe a set of records for office and field, including pumping station efficiency data," but these records were omitted for lack of time. The present paper is prepared in response to requests for the pumping station cost and efficiency records previously omitted.

The engineering and accounting records described herein have been in use by the water department of the city of New York for the past four years. Their importance is shown by the fact that the largest item of expenditure by the department is for operation and maintenance of pumping stations. There is spent annually upwards of $4,000,000 for the operation and maintenance of the city's present water supply system. Over one-third of this sum is spent for the 50 low-pressure pumping stations in the five boroughs comprising the greater city.

When the burden of increasing taxation became so great that it was reflected in the efforts of administrative officials to reduce the budget, the water department naturally directed special attention to its largest single expenditure, pumping stations. Since about 70 per cent of the total cost of operating the 50 stations was expended for the Borough of Brooklyn, in which 31 stations are located, this paper will be limited to a consideration of the economies effected in that borough, in an endeavor to prove the value of the records in question.

The cost and efficiency system was not installed solely for the purpose of effecting immediate economies. On account of the relatively high cost of operation of the Brooklyn water system, where all water has to be pumped, it was planned to introduce the cheaper

[1] Read before the Richmond convention, May 8, 1917.

gravity supply of the new Catskill system just as soon as it became available. The urgency of this plan will be appreciated from the following comparison of the additional outlay per million gallons required to utilize the two supplies.

	per million gallons
Catskill gravity supply	$0.50
Brooklyn pumped supply	17.20

These figures, of course, do not take into account the heavier capital expenditures necessary to provide a gravity supply instead of a pumped supply. The comparison is made from the standpoint of cost of operation only, on the assumption that the capital expenditures for the Catskill system were necessary in any event to insure meeting the increasing demands of the city in the future. With the completion of each section of the Catskill system, the new supply was gradually introduced in the different boroughs. Some of the stations were shut down before others. The institution of these cost and efficiency records, then, was also for the purpose of enabling the department to determine intelligently which stations were the most expensive to operate in point of performance, so that such stations might be shut down altogether and others manned and held in reserve, thus effecting the greatest economies possible.

Further, it was estimated that after shutting down the entire Brooklyn pumped supply, the combined yields of the old Croton and the new Catskill (Esopus) systems will be insufficient to meet the increased water consumption of the city estimated for the year 1922. In that year, it may be necessary to start the gradual resumption of pumping. The gradual reintroduction of the Brooklyn pumping stations, it is estimated, will continue until about 1928. The order in which the stations should be brought back into service would again be determined from the cost and efficiency data. It is likewise estimated that the discontinuance of pumping will be repeated again about 1929, with the introduction of the projected Schoharie development, and again gradually resumed commencing about 1933. The dates mentioned in connection with the discontinuance and resumption of Brooklyn pumping in the future are estimates based upon normal increase of population. For our present purposes, their accuracy is immaterial. The fact that the second resumption of pumping may not commence until say 1940 instead of 1933 does not affect the number of times stations will

ultimately have to be shut down and later resumed. With the introduction of a new supply, particular stations will be shut down. On the other hand, the subsequent failure of the new yield to keep pace with increasing demands will necessitate their resumption. The changes in each case will be dictated by the data furnished by the cost and efficiency records described herein.

The purpose of these records is, then, twofold, as follows:

First. To determine where economies can be effected in cost of operation and maintenance

Second. To enable the department to contract and expand its present Brooklyn system in a way which will be consistent with economy and efficiency.

The economies already effected in cost of operation and maintenance of the Brooklyn pumping stations for the three years ended December 31, 1915, are shown in the accompanying table.

Comparative cost of operation and maintenance, Brooklyn pumping stations, 1912 to 1915

YEAR	TOTAL PUMPAGE	TOTAL COST	COST PER MILLION GALLONS PER FOOT	AVERAGE DUTY, MILLION FOOT-POUNDS PER 100 POUNDS COAL
	million gals.		*cents*	
1912	110,406	$1,115,820	9.4	37.9
1913	106,284	996,038	9.0	40.2
1914	117,043	953,423	7.6	42.8
1915	113,973	908,666	7.9	42.3

Annual Increases (I) or Decreases (D)

PERIOD	TOTAL PUMPAGE		TOTAL COST		COST PER MILLION GALLON FEET		AVERAGE DUTY	
From To	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent
1912–1913	(D) 4,122	3.8	(D) $119,782	10.7	(D) 0.4	4.3	(I) 2.3	6.1
1913–1914	(I) 10,759	10.1	(D) 42,615	4.3	(D) 1.4	15.5	(I) 2.6	6.5
1914–1915	(D) 3,070	2.6	(D) 44,757	4.7	(I) 0.3	4.0	(D) 0.5	1.1

It will be seen from the above that the reduction in the cost of operation and maintenance in 1913 is considerable, about $120,000, or a saving of 10.7 per cent in 1912 costs. The fact that 1913 was the first year in which the efficiency system was in full operation may be the explanation for this large reduction in costs. The de-

crease in 1913 pumpage, 4122 gallons, (3.8 per cent of 1912) combined with the first factor of reduced total costs, shows a decrease of 0.4 cent in cost per million gallons raised one foot. The average duty, the principal factor of which is coal, shows an increase over 1912 of 2.3 points, about 6.1 per cent. Although the saving in operating costs for the next year, 1914, was not comparatively large, the total being $42,615 less than that of 1913, it will be seen that considerably more water was pumped, 10,759,000,000 gallons, or 10.1 per cent more than in 1913. Combining these two factors we find a decrease of 1.4 cents per million gallons per foot, or a decrease per unit of 15.5 per cent from the results of the preceding year. This indicates that the figures for 1914 were decidedly more satisfactory than the improved results of 1913, which showed a decreased cost per unit of only 4.3 per cent. The coal efficiency likewise shows improvement to the extent of 2.6 points increase in average duty. The reduction of unit cost per million gallons per foot from 9.4 cents in 1912 to 7.6 cents in 1914, shows a saving of nearly 20 per cent. The advent of the new (present) administration, which was quick to appreciate the value of these records, no doubt was responsible for the good showing. Although the results for 1915 did not reflect improvement over 1914, they were almost as good as for the previous year. This is considered satisfactory, in view of the practical maintenance of 1914 standards in the face of increasing prices paid for labor, materials and supplies. As the European war has played general havoc with prices of labor, materials and supplies, and particularly with the cost of coal, it will be necessary to make allowances for this abnormal condition when making comparison of 1914 and prior figures with operating costs for 1915 and subsequent years.

As to the savings to be effected in intelligently contracting and expanding the Brooklyn system with the aid of these records, the annual economies will be governed by the actual new gravity supplies available and the increasing water demands of the city in each year. In this connection, it is stated by Commissioner William Williams:

> All of the 33 pumping stations in the boroughs of Brooklyn and Queens and all but one in Richmond will be placed in reserve, and thereafter the operating expenses of the department will be reduced by over $650,000 per annum, this after due allowance for maintaining and operating the Catskill system.

STATION No.....

STATION .....

SUMMARY OF RECORDS FROM DAILY REP(

Day of Month	No. IN USE		Services in use R, T, C, D-S.	FEED WATER		Auxil's Running *No. in Use Multiplied by No. of Hrs.*	Mixture of Coal and Sizes	Coal Burned in 24 Hours *Pounds*
	Boilers	Engines		Cubic Feet to Boilers in 24 Hours	Average Temp. *Deg. F.*			
1	2	3	4	5	6	7	8	9
							(85) Previous Local Efficiency S	

THE CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY

ENGINEERING BUREAU

MONTHLY REPORT—PUMPING STATIONS

ROM DAILY REPORTS					E
Coal Burned in 24 Hours *Pounds*	Water Pumped in 24 Hours *Gallons*	Total Lift *Feet*	Million Gallons Raised One Foot High	Million Gallons Raised One Foot High Per Pound of Coal	HORS Total c Wate Cylinde Per Min
9	10	11	12	13	14
s Local Efficiency Standards to be Surpassed, viz:					

REPORT No.....

S ..... MONTH..... ENDING.....191.....

	EFFICIENCY RECORDS				SUPPLIES USED				
Ilons High Coal	HORSE POWER		Total Heat of Steam at Boiler Pressure	Equivalent Evaporation From and At 212° Fahr. Per Pound of Coal	Cylinder Oil in Gallons	Engine Oil in Gallons	Grease in Pounds	Waste in Pounds	Out-door Temperature at 8 A. M.
	Total of Water Cylinders Per Minute	Lbs. Coal Per Water H. P. Hour							
	14	15	16	17	18	19	20	21	22

The commissioner does not include depreciation, nor is this item included in any of the foregoing figures. Steps are now being taken to incorporate depreciation in future costs.

Incidentally, it might be added that should the Board of Aldermen approve the department's plans, further economies will be effected with the extension of universal metering. It is estimated by Deputy Commissioner Delos F. Wilcox that were all residences metered i ı addition to business premises, the resumption of pumping in Brooklyn would be delayed several years, during which large savings would result through the use of gravity instead of pumped water.

The cost and efficiency records may be divided into the following sections:

First. Collation of cost data, consisting of labor, material and supplies.

Second. Compilation of statistics, showing amount of pumpage, consumption of coal, etc.

Third. Computation of efficiency records, showing engine and boiler performances.

Fourth. Determination of unit costs.

The cost data for labor are collated from weekly or monthly payroll analysis sheets, the basis for which is found in the character and amount of work performed shown on each employee's time sheets. The cost of material and supplies is obtained from priced requisitions on storekeeper or vendor's invoices, which are functionalized according to use. The consumption of coal is obtained from the enginemen's daily reports. A proper functional classification of accounts for this purpose is given in the author's article "Interpretation of Water Works Accounts" as follows:

Pumping station costs

Superintendence
Operation
- Labor
- Fuel
- Packing, oil and waste
- Minor equipment
- Miscellaneous

Maintenance
  Repairs and replacements
    Buildings and grounds
    Boiler plant
    Pumping machinery
    Miscellaneous equipment
  Depreciation
    Buildings
    Boiler plant
    Pumping machinery
    Miscellaneous equipment
    Computed burden (overhead)

TOTAL COST OF OPERATION

The compilation of statistics of pumpage, etc., is made from the enginemen's daily reports of pumping station operation made on a blank reproduced herewith. This report contains a record of the performances of each engine during the different watches. It shows the relative efficiency of the different employees on duty during the three watches. The principal facts indicated by it are:

1. Hours of operation
2. Engine counter readings
3. Actual gallons pumped
4. Lift of water—both intake and discharge
5. Hourly steam pressure
6. Hourly condenser vacuum readings
7. Temperatures of feed water and flue gas
8. Feed water meter readings
9. Coal summary
10. Boilers in service
11. Engine constant and method of determination.

The computation of efficiency records is made from the enginemen's daily reports above described on the accompanying form. The result of each day's operation is copied from the enginemen's report and entered on a separate line in columns 2 to 11, which are summarized at the end of the month. The following formulas cover the computation of efficiency data for each month.

STATION No. _____ DE

STATION _____

WATCH No.	ENGINE No.	ENGINE HOURS			ENGINE COUNTER READINGS			TOTAL REVOLUTIC
		START	STOP	RUN	START	STOP	REVOLUTIONS	
1	2	3	4	5	6	7	8	9
1								
2								
3								
1								
2								
3								
1								
2								
3								
1								
2								
3								
1								
2								
3								
1								
2								

CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY

BUREAU OF WATER SUPPLY

DAILY REPORT—PUMPING STATIONS

ONS	TOTAL REVOLUTIONS	ENGINE CONSTANT	ACTUAL GALLONS PUMPED AND DISTRIBUTION			TIME	INTAKE HEAD. SUCTION OR PRESSURE
	9	10	11	12	13	14	15
						1 a. m.	
						2 a. m.	
						3 a. m.	
						4 a. m.	
						5 a. m.	
						6 a. m.	
						7 a. m.	
						8 a. m.	
						9 a. m.	
						10 a. m.	
						11 a. m.	
						12 (noon)	
						1 p. m.	
						2 p. m.	
						3 p. m.	
						4 p. m.	
						5 p. m.	
						6 p. m.	
						7 p. m.	
						8 p. m.	
						9 p. m	
						10 p. m.	
						11 p. m.	

TRICITY

REPORT No. .....

S

DATE ..... 191__

ON	TIME	INTAKE HEAD. SUCTION OR PRESSURE	DISCHARGE HEAD			STEAM PRESSURE AT STATION	CONDENSER VACUUM AT ENGINE (INCHES OF MERCURY)						FEED WATER TEMP. ENTERING ECON. OR BOILER	FLUE GAS TEMP. ENTERING ECON. OR STACK
	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	1 a. m.													
	2 a. m.													
	3 a. m.													
	4 a. m.													
	5 a. m.													
	6 a. m.													
	7 a. m.													
	8 a. m.													
	9 a. m.													
	10 a. m.													
	11 a. m.													
	12 (noon)													
	1 p. m.													
	2 p. m.													
	3 p. m.													
	4 p. m.													
	5 p. m.													
	6 p. m.													
	7 p. m.													
	8 p. m.													
	9 p. m													
	10 p. m.													
	11 p. m.													

2											
3											
1											
2											
3											

TIME	FEED WATER METER READINGS *Unit*	COAL FIRED—WEIGHT AND KIND—(LBS.)			WEIGHT OF ASH (LBS.)
4 a. m.					
8 a. m.					
12 (noon)					
4 p. m.					
8 p m.					
12 p. m.					
Total					

WATCH NO.	ENT
1	
2	
3	

NOTE:—1

ENGINE CONSTANT *For Engine No.*

P

COAL SUMMARY FOR 24 HOURS (LBS.)

	KIND OF COAL			
A	COAL ON HAND BEGINNING OF FIRST WATCH			
B	COAL RECEIVED			
C	SUM OF A AND B			
D	COAL USED FOR PUMPING			
E	COAL USED FOR BANKING			
F	TOTAL COAL USED			
G	COAL ON HAND END OF LAST WATCH			

REMARKS:

		6 p. m.
		7 p. m.
		8 p. m.
		9 p. m.
		10 p. m.
		11 p. m.
		12 p. m.
	TOTALS	TOTALS

GHT
ASH
IS.)

BOILERS IN SERVICE			
WATCH NO.	ENTIRE WATCH	PART OF WATCH (HOURS)	
1			
2			
3			

(a) AVERAGE DISCHARGE HEAD	
(b) AVERAGE INTAKE HEAD	
(c) TOTAL HEAD FROM GAUGES	
(d) CORRECTION FOR HEAD	
(e) ACTUAL PUMPING HEAD	

NOTE: *— The data relating to Engine Constant is to be entered in the table below ONLY after each test for Pump slip, or when for any reason the Constant is changed.*

ENGINE CONSTANT = For Engine No.	THEORETICAL DISPLACEMENT PER REVOLUTION = Gallons	CORRECTION FACTOR FOR ACTUAL DISPLACEMENT x Factor = Gallons	ENGINE CONSTANT OR ACTUAL PUMPAGE DETERMINED BY
=		x =	
=		x =	
=		x =	
=		x =	
=		x =	
=		x =	

FIRST WATCH
FROM
TO

SECOND WATCH
FROM
TO

THIRD WATCH
FROM
TO

REMARKS:

	6 p. m.														
	7 p. m.														
	8 p. m.														
	9 p. m.														
	10 p. m.														
	11 p. m.														
	12 p. m.														
	TOTALS														

AGE DISCHARGE HEAD			
AGE INTAKE HEAD			
L HEAD FROM GAUGES			
ECTION FOR HEAD			
AL PUMPING HEAD			

AVERAGES OF PRESSURES AND TEMPERATURES

STEAM PRESSURE	CONDENSER VACUUM INCHES OF MERCURY						FEED TEMP.	FLUE GAS TEMP.

FIRST WATCH

FROM ..... M.
TO ..... M. *Engineman in Charge*

SECOND WATCH

FROM ..... M.
TO ..... M. *Engineman in Charge*

THIRD WATCH

FROM ..... M.
TO ..... M. *Engineman in Charge*

Engineman in Charge of Station

TABLE 1

Properties of steam

GAGE READINGS	THERM. READINGS	TOTAL HEAT FOR USE IN COLUMN 16	GAGE READINGS	THERM. READINGS	TOTAL HEAT FOR USE IN COLUMN 16
60	307.4	1175.7	155	368.2	1194.2
65	311.8	1177.0	160	370.5	1194.9
70	316.0	1178.3	165	372.8	1195.7
75	320.0	1179.6	170	375.1	1196.3
80	323.9	1180.7	175	377.3	1197.0
85	327.6	1181.8	180	379.5	1197.7
90	331.1	1182.9	185	381.6	1198.3
95	334.5	1184.0	190	383.7	1199.0
100	337.8	1185.0	195	385.7	1199.6
105	341.0	1185.9	200	387.7	1200.2
110	344.1	1186.9	205	389.7	1200.8
115	347.1	1187.7	210	391.8	1201.4
120	350.0	1188.7	215	393.6	1202.0
125	352.8	1189.5	220	395.3	1202.5
130	355.5	1190.4	225	397.3	1203.1
135	358.2	1191.2	235	401.0	1204.2
140	360.7	1192.0	245	404.4	1205.3
145	363.3	1192.7	255	407.8	1206.3
150	365.7	1193.5	265	411.0	1207.3

Column 12 = Col. 10 × Col. 11.
Column 13 = Col. 12 ÷ Col. 9.
Column 14 = Col. 12 × 0.0000001758
Column 15 = Col. 9 ÷ (Col. 14 × 24)
Column 16 = Take figure for "Total Heat" in Table 1 corresponding to nearest gauge pressure.
Column 17 = Col. 16 − (Col. 6–32) × (Col. 5 ÷ Col. 9) × 0.0647

That these cost and efficiency records are practical is proved by the valuable statistics which they afford the department. Inasmuch as they are kept for each station separately and in a manner that will afford ready comparison between them, such records should be adaptable to any hydraulic pumping stations. Not only do they afford a comparison between different stations, but the performance and unit cost of each station by itself can be compared independently, one period with another. The stations in Brooklyn vary in lift from 14.2 to 186 feet: in daily pumpage from 0.1 to 84.1

million gallons; in average duty from 6.7 to 60.3, and in total cost per million gallons raised 1 foot from 4.8 cents to $1.43. These varying figures will point the way for future administration of the department, so far as pumping station operation is concerned.

As the system above described is a uniform one and suited to small as well as to large works, both municipal and private, it is to be hoped that such of the numerous cities having pumping plants which do not now have similiar cost and efficiency records will adopt this or a modification of this system. Certainly, the financial benefits which have already accrued to the City of New York would seem to indicate the advisability of such a course. The need of such records has been pointed out to the private water companies operating in certain outlying districts of New York City, during the author's connection with the rate investigations and valuation of these plants. Some of the companies have already acted on this suggestion and adopted this plan of record-keeping. It is confidently expected that gratifying results will be obtained before long, and not only will these companies be furnished with data which will enable them to reduce unit costs of operation and maintenance, but the general efficiency of the employees will be increased and a consequent improvement of service result.